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Source: Journal of Wildlife Diseases, 18(3) : 321-338

Published By: Wildlife Disease Association

URL: https://doi.org/10.7589/0090-3558-18.3.321

EFFECTS OF RATION, SEASON AND ANIMAL HANDLING ON COMPOSITION OF BISON AND CATTLE BLOOD[1]

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Abstract: Composition of ration and season of sampling markedly affected the composition of blood in six tamed bison *(Bison bison)* steers and eight Hereford cattle *(Bos taurus)* steers. Observed values extended reported ranges for albumin, phosphorus and blood urea nitrogen (BUN) in bison serum. There were several differences between species in blood composition. In particular, erythrocytic and BUN values were higher in bison than in cattle. Overall mean values for bison and cattle receiving experimental rations were, respectively: BUN, 17.1 mg/dl and 14.1 mg/dl; hemoglobin, 17.8 g/dl and 13.3 g/dl; packed cell volume (PCV), 47.6% and 35.6%; red blood cells, $9.3 \times 10^6/mm^3$ and $8.2 \times 10^6/mm^3$; mean corpuscular volume (MCV), 51.3 μ^3 and 43.5 μ^3; mean corpuscular hemoglobin, 18.9 pg and 16.1 pg. The significant changes in blood composition associated with changes in ration composition support the use of blood composition as an index of nutritional status. There were no sex-specific differences in blood of 20 bison from Elk Island National Park and 34 bison from Wood Buffalo National Park, Alberta. Alkaline phosphatase (ALP) level was higher in juvenile than in adult bison. Impoundment of wild bison for 24 hr was accompanied by a decrease in BUN and an increase in PCV. Wild bison that were killed during handling had significantly higher blood levels of ALP, glutamate oxaloacetate transaminase, MCV and phosphorus.

INTRODUCTION

North American bison *(Bison bison)* are widespread and are increasing in numbers and in economic importance. Existing baseline data on bison blood composition (Marler, 1975; Mehrer, 1976; Keith et al., 1978), represent a large part of the range of conditions under which bison live. However, several factors affecting bison blood composition require investigation in order to properly evaluate blood data. Bison are intractable animals that can become highly excited when handled (Richmond et al., 1977; Hudson and Tennessen, 1978), and handling stress and trauma can produce marked changes in blood composition (Franzmann and Thorne, 1970; Franzmann, 1971; 1972; Wesson et al., 1979). Bison display seasonal variations in food intake, growth, and metabolism (Christopherson et al., 1979; Hawley et al., 1981a), and these types of variations have been associated with altered blood profiles in other species (Ozoga and Verme, 1970; Seal et al., 1972; Coblentz, 1975; Hyvärinen et al., 1975; Bahnak et al., 1979). Ration composition can also markedly affect blood composition of ruminants (Torell et al., 1974; Kirkpatrick et al., 1975). The objective of this study was to measure the composition of bison blood under a variety of physiological and environmental conditions and to evaluate the causes of observed differences. The effects of protein and energy levels in rations and of season on blood composition were

[1] This study was supported by Canadian Wildlife Service Contract No. 0SZ5-0285.

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studied with tame, confined bison. Comparable data were obtained for cattle *(Bos taurus)* to provide a basis for comparisons between species. Differences between herds and among sex and age classes were studied by sampling bison from Elk Island National Park (EINP) and Wood Buffalo National Park (WBNP) in Alberta, Canada. Sampling park bison also provided the opportunity to compare samples from animals of varying tractability and requiring different handling methods.

MATERIALS AND METHODS

Animals

Six yearling bison steers and eight yearling Hereford steers were used to investigate the effects of ration and season on blood composition under feedlot conditions. The bison were obtained as calves from EINP in September 1975. Hereford steers of the same age were obtained in March 1976. All animals were treated similarly and received the same rations before and after the experimental periods. The long-term handling and growth of the animals have been outlined (Reynolds et al., 1982).

Samples were also obtained from 20 bison in EINP and 34 bison in WBNP of mixed sex and age classes. The bison at EINP were continually enclosed within fenced rangeland and were occasionally corralled and handled. The bison at WBNP were free-ranging and wild but were occasionally captured in wing-fenced corrals and treated for disease (Hudson and Tennessen, 1978).

Experimental Rations

Four rations were formulated to contain high protein, high energy (HPHE), high protein, low energy (HPLE), low protein, high energy (LPHE) and low protein, low energy (LPLE), (Table 1). All constituents were ground in a hammer mill. Chemical analyses were as described by Hawley et al. (1981a). Animals were held continuously outdoors and experiments were conducted in summer and winter. Three of six bison and four of eight cattle were fed the same ration *ad libitum* in the same pen. The remaining animals were fed a different ration in an adjacent pen. The rations were tested in pairs, the HPHE and HPLE rations first and the LPHE and LPLE rations second, with animals and rations randomly assigned to pens in each instance. Before testing the first pair of rations and between testing the first and second pairs, all animals received a barley and hay ration of 12.4% crude protein (CP) and 68% digestible energy (DE) for an equilibration period of 14 days. All animals were conditioned to the experimental rations for 16 days prior to blood sampling.

Sampling

For each ration in each season, blood was drawn from each feedlot animal on four alternate days over one wk for a total of 12 bison samples (3 animals $\times$ 4 days) and 16 cattle samples (4 animals $\times$ 4 days). Sampling dates in summer for HPHE and HPLE rations were 24, 26, 28, 30 August 1976 and for LPHE and LPLE rations were 28, 30 September, 2, 4 October 1976. In winter, sampling dates for HPHE and HPLE rations were 26, 28 February, 2, 4 March 1977 and for LPHE and LPLE rations were 2, 4, 7, 9 April 1977.

Individual animals were physically restrained in a cattle squeeze immediately prior to and during sampling. Blood was obtained by jugular venopuncture using a syringe and 18 gauge needle. Blood for serum samples was transferred to untreated 10 ml Vacutainer [4] tubes. Blood for hematological analyses was transferred to 3 ml EDTA[5]-treated tubes.[4] Heart rate and rectal

[4] Kimble-Terumo, Inc., Elkton, Maryland 21921, USA.

[5] Ethylenediaminetetracetate

Table 1. Experimental rations fed to bison and Hereford steers.

Constituents		Composition, % of dry matter			
		HPHE[a]	HPLE	LPHE	LPLE
Wheat straw		35.0	76.0	40.0	80.0
Beet pulp		4.0	2.0	5.0	5.0
Rolled barley		37.25		43.25	4.25
Soybean meal		12.0	19.25		7.0
Beet molasses		5.0		5.0	
Tallow		4.0		4.0	1.0
Ground limestone		0.25	0.25	0.25	0.25
Dicalcium phosphate		1.0	1.0	1.0	1.0
Salt (cobalt-iodized)		0.5	0.5	0.5	0.5
Vitamin premix[b]		1.0	1.0	1.0	1.0
Total		100.0	100.0	100.0	100.0
Nutrients					
Crude protein, %	Summer	12.6	11.1	9.1	6.6
	Winter	11.8	9.6	8.5	7.3
Digestible energy, kcal/g[c]	Summer	3.2	2.5	3.8	2.3
	Winter	3.1	2.4	3.2	2.6
Calcium,%	Summer	0.3	0.3	0.3	0.3
	Winter	0.3	0.4	0.4	0.3
Phosphorus,%	Summer	0.4	0.3	0.3	0.2
	Winter	0.4	0.3	0.3	0.2

[a]HPHE = high protein high energy; HPLE = high protein low energy; LPHE = low protein high energy; LPLE = low protein low energy.

[b]Provided 3,960 IU vitamin A and 880 IU vitamin D per kg of ration.

[c]Calculated using the formula: total digestible nutrients (TDN) = 95.88 - (0.9111 × acid detergent fiber) and assuming 1kg TDN = 4.4 Mcal digestible energy.

temperatures of most animals were measured during sampling in the summer blood experiments. Animal stress during sampling was estimated subjectively based on the struggling and visible disquiet of the animals. Laboratory analyses were conducted immediately after sampling.

Blood samples from bison at EINP and WBNP were obtained from tail veins. The EINP samples were collected on the afternoon of 22 March 1977 from animals that had been corralled two days previously. Animals were loosely confined in chutes immediately prior to sampling. Collection tubes were as described previously. All samples were stored on ice overnight and analyzed the next morning. Bison at WBNP were herded by helicopter into holding corrals on the morning of 1 June 1977. Twenty-three bison were sampled on 1 June and 11 bison on 2 June. Forage and water were available continuously to the animals while in the holding corral. Animals were driven into chutes immediately prior to sampling. Five of the bison sampled on 2 June were juveniles (animals up to and including 2-yr old) which had died from injuries incurred during handling. Blood samples were collected from the heart of these animals shortly after death. Samples taken on 1 June were centrifuged and the serum stored on ice. Samples taken on 2 June were stored on ice without centrifugation. Laboratory

analyses of all WBNP samples were conducted on 4 June.

Laboratory Analyses

Determinations were made for the 21 blood components listed in Table 2. Serum collected prior to 1 January 1977 was analyzed using an Abbott Biochromatic 100 analyzer.[n] Subsequent analyses for phosphorus (P), cholesterol, creatine phosphokinase (CPK), blood urea nitrogen (BUN), and alkaline phosphatase (ALP) were conducted with a Coulter Kemolab analyzer[j] and analyses of glutamate oxaloacetate transaminase (GOT) and glucose continued on the Abbott analyzer. All analyses were equated to results from the Abbott analyzer using equivalent standards. All hematological analyses were conducted with a Coutler Model S analyzer.[k] Total blood protein was measured using two methods. Total plasma protein (TPP) was measured using a total-solids refraction index. The measurement of total serum protein (TSP) involved a modified biuret reaction. Electrophoresis and quantification of serum proteins was performed with a Gelman electrophoretic unit and densitometer.[l] Total serum thyroxine (T_4) was measured with a competitive protein binding procedure using an Abbott Tetrasorb-125 kit.[m]

Statistical Analyses

Data from experiments with formulated rations were analyzed using a mixed model analysis of variance with species, season, energy level in the ration, and protein level in the ration as the main effects and with the variation within individuals (repeated observations on successive sampling days) nested within the variation among individuals (Sokal and Rohlf, 1969). The larger mean square was used as denominator in the F ratios to test the significance of fixed effects. Analyses of variance were also conducted using the means of within-animal replicates as data. With data from the park bison, analyses of variance were used to compare values between juveniles and adults, males and females, and animals on the day of capture versus those held overnight. Only live animals were included in these comparisons. Blood composition was compared between live and dead juveniles at WBNP using analysis of variance.

RESULTS

Experiments with Formulated Rations

The mean concentrations of blood components in animals receiving experimental rations are presented in Tables 2 and 3. All blood components varied significantly with at least one effect or interaction (Table 4). Detailed consideration of 3-way and 4-way interactions did not contribute greatly to our understanding of effects and were therefore deleted. In both species, the within-animal (among-day) variations of BUN, CPK, MCHC, albumin, β-globulin and TSP were significantly greater than the between-animal variations but displayed no consistent changes on successive sampling days (Table 5). The other components with significant within-animal variation tended to decrease on successive sampling days. When within-animal variation was removed by averaging replicates within individuals, there was a large decrease in degrees of freedom in the analyses of variance.

[n] ABA-100, Abbott Laboratories, Pasadena, California 91109, USA.

[j] 300 Sample Gamma Counter, Nuclear Chicago, Des Plaines, Illinois 60018, USA.

[k] Coulter Counter Model S, Coulter Electronics, Hialeah, Florida 33010, USA.

[l] Gelman, Montreal, Quebec H4S 1M7, Canada.

[m] Abbott Laboratories, Diagnostics Division, North Chicago, Illinois 60064, USA.

Table 2. Mean concentration ± one standard deviation of blood components in bison and cattle in summer.

	Bison (n = 12)				Cattle (n = 16)			
Component[a]	HPHE[b]	HPLE	LPHE	LPLE	HPHE	HPLE	LPHE	LPLE
BUN (mg/dl)	17.5 ± 2.4	24.6 ± 2.3	17.5 ± 3.2	19.2 ± 3.7	16.3 ± 2.0	15.9 ± 2.6	13.1 ± 2.5	14.2 ± 2.5
P (mg/dl)	8.1 ± 0.4	8.3 ± 0.6	6.9 ± 0.7	7.2 ± 1.0	8.2 ± 0.7	8.4 ± 1.2	7.1 ± 0.8	7.9 ± 1.1
ALP (IU/l)	94.2 ± 14.1	62.0 ± 9.1	88.0 ± 13.7	54.6 ± 11.0	81.8 ± 27.9	72.4 ± 15.8	95.7 ± 24.9	71.7 ± 15.2
CPK (IU/dl)	11.5 ± 2.4	11.9 ± 7.9	11.2 ± 5.9	13.3 ± 10.1	10.9 ± 1.7	13.0 ± 8.4	11.6 ± 3.1	10.8 ± 2.7
Chol (mg/dl)	92.2 ± 9.0	86.4 ± 13.4	82.5 ± 17.7	129.1 ± 11.2	107.4 ± 13.5	103.6 ± 20.3	99.8 ± 17.6	135.3 ± 22.9
GOT (IU/l)	89.7 ± 10.6	81.6 ± 8.8	86.3 ± 7.7	159.0 ± 54.8	70.7 ± 8.2	57.5 ± 12.2	69.7 ± 8.7	69.5 ± 11.9
Glucose (mg/dl)	84.7 ± 12.3	77.8 ± 7.6	75.5 ± 22.7	63.0 ± 18.7	87.2 ± 6.0	75.6 ± 7.9	72.8 ± 12.5	64.9 ± 11.3
Hgb (g/dl)	16.9 ± 0.3[c]	17.3 ± 1.3	16.6 ± 1.4	17.7 ± 1.0	12.0 ± 0.6	13.8 ± 1.2	12.3 ± 0.7	13.8 ± 0.9
PCV (%)	45.3 ± 1.4[c]	47.0 ± 2.6	43.9 ± 3.7	47.7 ± 3.2	31.8 ± 1.8	37.1 ± 3.6	32.2 ± 1.4	37.1 ± 2.7
RBC ($\times 10^6$/mm^3)	9.3 ± 0.4[c]	9.7 ± 0.6	8.9 ± 0.7	10.0 ± 0.7	8.0 ± 0.3	8.5 ± 0.7	7.7 ± 0.7	9.1 ± 1.0
MCV (μ^3)	48.2 ± 1.9[c]	48.4 ± 0.7	49.2 ± 1.7	47.7 ± 1.6	39.4 ± 1.4	43.8 ± 3.5	42.3 ± 4.8	40.8 ± 2.3
MCH (pg)	17.6 ± 0.7[c]	17.4 ± 1.0	18.1 ± 1.0	17.2 ± 0.6	14.7 ± 0.4	16.1 ± 1.3	15.7 ± 1.6	14.8 ± 0.8
MCHC (%)	35.9 ± 1.1[c]	35.6 ± 1.9	36.6 ± 1.2	35.8 ± 1.4	36.6 ± 0.7	36.1 ± 0.8	36.7 ± 0.9	35.7 ± 1.1
WBC ($\times 10^3$/mm^3)	7.3 ± 1.1[c]	7.8 ± 1.3	6.8 ± 0.7	8.1 ± 0.7	9.4 ± 0.8	8.7 ± 1.0	9.2 ± 1.3	10.0 ± 2.3
Albumin (g/dl)	3.6 ± 0.2	4.0 ± 0.3	4.1 ± 0.4	4.3 ± 0.4	3.5 ± 0.2	3.8 ± 0.2	3.5 ± 0.3	3.9 ± 0.4
α-glob (g/dl)	1.2 ± 0.1	1.1 ± 0.2	1.0 ± 0.3	1.1 ± 0.2	1.1 ± 0.1	1.1 ± 0.1	1.1 ± 0.3	1.1 ± 0.2
β-glob (g/dl)	0.7 ± 0.1	0.6 ± 0.1	0.7 ± 0.2	0.6 ± 0.1	0.9 ± 0.1	0.9 ± 0.1	0.8 ± 0.1	0.9 ± 0.1
γ-glob (g/dl)	1.7 ± 0.2	1.5 ± 0.2	1.5 ± 0.5	1.6 ± 0.4	1.5 ± 0.2	1.7 ± 0.2	1.4 ± 0.3	1.8 ± 0.4
TPP (g/dl)	7.2 ± 0.3[c]	7.0 ± 0.2	7.1 ± 0.5	7.4 ± 0.3	7.0 ± 0.2	7.3 ± 0.2	6.9 ± 0.3	7.5 ± 0.3
TSP (g/dl)	7.3 ± 0.3	7.2 ± 0.4	7.4 ± 0.6	7.6 ± 0.4	7.0 ± 0.2	7.5 ± 0.3	6.9 ± 0.4	7.7 ± 0.3
T_4 (μg/dl)[d]	5.6 ± 1.6	4.5 ± 0.7	5.7 ± 1.2	3.4 ± 0.7	7.9 ± 1.3	6.1 ± 0.3	7.6 ± 1.0	6.0 ± 0.6

[a] BUN = blood urea nitrogen; P = phosphorus; ALP = alkaline phosphatase; CPK = creatine phosphokinase; Chol = cholesterol; GOT = glutamate oxaloacetate transaminase; Hgb = hemoglobin; PCV = packed cell volume; RBC = red blood cells; MCV = mean corpuscular volume; MCH = mean corpuscular hemoglobin; MCHC = mean corpuscular hemoglobin concentration; WBC = white blood cells; glob = globulin; TPP = total plasma protein; TSP = total serum protein; T_4 = thyroxine.

[b] See Table 1 for abbreviations.

[c] n = 11

[d] Bison n = 3; cattle n = 4.

Table 3. Mean concentration ± one standard deviation of blood components in bison and cattle in winter.

	Bison (n = 12)				Cattle (n = 16)			
Component[a]	HPHE[b]	HPLE	LPHE	LPLE	HPHE	HPLE	LPHE	LPLE
BUN (mg/dl)	18.5 ± 2.5	19.4 ± 4.5	8.3 ± 1.9	12.1 ± 2.8	16.9 ± 3.0	17.4 ± 4.1	9.4 ± 1.4	9.8 ± 1.6
P (mg/dl)	7.5 ± 0.6	7.7 ± 1.0	7.4 ± 0.5	7.5 ± 0.7	8.2 ± 0.9	8.9 ± 1.1	7.4 ± 1.0	8.3 ± 0.9
ALP (IU/l)	83.2 ± 11.5	64.2 ± 6.3	105.2 ± 15.1	81.5 ± 17.2	79.5 ± 21.9	62.0 ± 12.5	83.4 ± 28.3	105.2 ± 24.6
CPK (IU/dl)	14.6 ± 5.1	10.3 ± 3.0	13.2 ± 5.9	9.8 ± 4.5	16.6 ± 2.9	13.5 ± 3.5	22.9 ± 20.4	11.4 ± 3.5
Chol (mg/dl)	123.8 ± 6.0	87.9 ± 5.8	148.4 ± 17.6	129.2 ± 30.6	155.3 ± 9.6	94.7 ± 18.3	186.0 ± 32.7	129.1 ± 25.7
GOT (IU/l)	90.8 ± 8.0	96.5 ± 21.0	83.5 ± 4.4	88.2 ± 20.7	88.6 ± 14.6	81.9 ± 8.5	94.2 ± 27.4	74.1 ± 10.0
Glucose (mg/dl)	67.8 ± 10.7	63.1 ± 7.4	72.6 ± 6.3	70.2 ± 8.9	66.1 ± 10.4	60.1 ± 5.2	70.3 ± 6.7	67.7 ± 5.6
Hgb (g/dl)	17.5 ± 0.9[c]	18.1 ± 0.9	19.1 ± 0.5	18.9 ± 1.3	12.9 ± 1.3	13.6 ± 1.0	13.6 ± 0.7	14.4 ± 1.2
PCV (%)	46.8 ± 2.6[c]	47.6 ± 2.1	51.7 ± 1.1	50.6 ± 3.6	34.4 ± 3.6	36.6 ± 3.7	37.0 ± 2.3	38.4 ± 3.7
RBC ($\times 10^6$/mm^3)	8.5 ± 0.5[c]	9.1 ± 0.3	9.1 ± 0.2	9.4 ± 0.8	7.4 ± 0.5	8.5 ± 0.9	8.0 ± 0.4	8.3 ± 0.8
MCV (μ^3)	55.1 ± 1.6[c]	52.5 ± 1.9	56.0 ± 1.4	53.3 ± 2.7	46.6 ± 5.3	43.1 ± 2.5	45.6 ± 2.2	46.1 ± 5.6
MCH (pg)	20.2 ± 0.4[c]	19.4 ± 0.8	21.2 ± 0.4	20.4 ± 1.3	17.0 ± 2.0	15.7 ± 1.0	17.2 ± 0.7	17.7 ± 2.2
MCHC (%)	36.5 ± 0.8[c]	36.6 ± 1.1	36.4 ± 1.0	36.7 ± 0.7	36.3 ± 0.7	36.0 ± 1.4	36.1 ± 0.7	36.8 ± 1.6
WBC ($\times 10^3$/mm^3)	6.6 ± 1.2[c]	5.9 ± 0.7	7.0 ± 1.0	7.7 ± 1.0	8.0 ± 0.7	9.2 ± 2.1	9.0 ± 1.2	8.9 ± 2.1
Albumin (g/dl)	3.7 ± 0.3	4.0 ± 0.4	3.6 ± 0.2	3.7 ± 0.4	3.3 ± 0.2	3.5 ± 0.4	3.3 ± 0.2	3.4 ± 0.2
α-glob (g/dl)	1.2 ± 0.1	1.0 ± 0.1	1.3 ± 0.1	1.3 ± 0.2	1.1 ± 0.1	1.1 ± 0.2	1.3 ± 0.2	1.1 ± 0.2
β-glob (g/dl)	0.6 ± 0.1	0.6 ± 0.1	0.7 ± 0.1	0.6 ± 0.1	0.8 ± 0.1	0.8 ± 0.1	0.8 ± 0.1	0.9 ± 0.1
γ-glob (g/dl)	1.9 ± 0.2	1.9 ± 0.4	2.0 ± 0.3	2.0 ± 0.4	1.7 ± 0.1	2.0 ± 0.2	1.8 ± 0.2	2.1 ± 0.2
TPP (g/dl)	7.1 ± 0.3[c]	7.1 ± 0.3	7.2 ± 0.3	7.2 ± 0.3	7.0 ± 0.1	7.3 ± 0.2	7.1 ± 0.1	7.3 ± 0.2
TSP (g/dl)	7.3 ± 0.4	7.4 ± 0.4	7.7 ± 0.5	7.6 ± 0.6	6.9 ± 0.2	7.4 ± 0.3	7.1 ± 0.4	7.5 ± 0.4
T_4 (μg/dl)[d]	5.8 ± 1.6	5.6 ± 1.0	5.3 ± 0.4	5.1 ± 0.8	7.4 ± 0.8	4.7 ± 1.9	7.2 ± 2.3	5.6 ± 0.9

[a] See Table 2 for abbreviations.
[b] See Table 1 for abbreviations.
[c] n = 11.
[d] Bison n = 3; cattle n = 4.

Table 4. Significance of effects in analyses of variance of blood components.

	Effects[a]									
	Main				Interactions					
Component[b]	A	P	E	S	A×P	A×E	A×S	P×E	P×S	E×S
BUN	***[c]	***	***	***		***	***		***	
P	***	***	***						*	
ALP		***	***			***			***	**
CPK			*	*			*			**
Chol	***	***	***	***		**		***	***	***
GOT	***	**			*	***	***	***	***	**
Glucose		*	***	***					***	*
Hgb	***	***	***	***		*	*		**	**
PCV	***	***	***	***		**			***	***
RBC	***	*	***	***						
MCV	***			***			*			**
MCH	***	**		***			**		**	
MCHC										**
WBC	***	*		**						
Albumin	***		***	***					***	
α-glob		*	*						***	
β-glob	***	*		**	*	***		*	**	**
γ-glob			**	***		**				
TPP			***			***		*		
TSP	***	**	***			***				
T_4	***		***				*			

[a]A = animal species; P = protein in ration; E = energy in ration; S = season.
[b]See Table 2 for abbreviations.
[c]*P<0.05; **P<0.01; ***P<0.001.

Table 5. Mean concentration ± one standard deviation on successive sample days of blood components for which within-animal variation significantly (P<0.05) exceeded between-animal variation.

	Day[a]			
Component[b]	1	2	3	4
BUN (mg/dl)	15.2 ± 4.6	16.3 ± 5.2	15.2 ± 5.2	15.1 ± 4.4
P (mg/dl)	8.0 ± 1.0	7.9 ± 1.0	7.8 ± 0.9	7.6 ± 1.0
CPK (IU/dl)	12.7 ± 4.1	13.4 ± 11.3	14.0 ± 8.9	12.0 ± 4.8
Glucose (mg/dl)	78.0 ± 12.3	66.7 ± 10.7	69.8 ± 15.3	70.0 ± 9.4
PCV (%)	41.7 ± 7.2	41.0 ± 7.3	40.1 ± 6.8[c]	39.8 ± 6.6[c]
MCHC (%)	36.2 ± 1.3	36.4 ± 1.0	36.1 ± 1.1[c]	36.5 ± 1.2[c]
Albumin (g/dl)	3.7 ± 0.4	3.6 ± 0.4	3.8 ± 0.5	3.6 ± 0.4
α-glob (g/dl)	1.2 ± 0.2	1.2 ± 0.2	1.1 ± 0.2	1.1 ± 0.2
β-glob (g/dl)	0.8 ± 0.2	0.8 ± 0.1	0.8 ± 0.1	0.8 ± 0.2
γ-glob (g/dl)	1.8 ± 0.3	1.8 ± 0.3	1.7 ± 0.4	1.7 ± 0.3
TPP (g/dl)	7.2 ± 0.3	7.2 ± 0.3	7.0 ± 1.0	7.0 ± 1.0
TSP (g/dl)	7.4 ± 0.5	7.3 ± 0.5	7.4 ± 0.4	7.2 ± 0.4

[a]On each day, n = 56.
[b]See Table 2 for abbreviations.
[c]n = 55.

Nevertheless, all blood components except mean corpuscular hemoglobin concentration (MCHC) varied significantly with at least one main effect or interaction. There was some sorting of rations by both species, especially of the LPLE ration in the winter. This was a possible source of variation in blood composition which was not tested.

Species Comparisons

Many of the differences between bison and cattle involved erythrocytes (Tables 2 and 3). Significantly different ($P<0.001$) overall mean erythrocytic values for bison and cattle were, respectively: red blood cells (RBC), $9.3 \times 10^6/mm^3$ and $8.2 \times 10^6/mm^3$; mean corpuscular volume (MCV), 51.3 μ^3 and 43.5 μ^3; mean corpuscular hemoglobin (MCH), 18.9 pg and 16.1 pg; hemoglobin concentration (Hgb), 17.8 g/dl and 13.3 g/dl; packed cell volume (PCV), 47.6% and 35.6%. Several other notable components varied significantly between species. Overall mean BUN levels in bison and cattle were, respectively, 17.1 mg/dl and 14.1 mg/dl. Cholesterol and white blood cells (WBC) were significantly higher in cattle and GOT was significantly higher in bison (Table 4). Glucose, CPK, and ALP did not vary significantly ($P>0.05$) between species.

Ration Comparisons

Most components that varied significantly with protein level in the ration also varied significantly with energy level in the ration (Table 4). Blood urea nitrogen increased with increased CP and decreased with increased DE in the ration. Within each season, the response of BUN to CP levels was similar at both energy levels, but BUN was more sensitive to CP content in winter than in summer. The depressive effect of increased DE on BUN was greater in bison than in cattle and the animal species $\times$ energy interaction was significant (Table 4). Blood urea nitrogen was numerically greater in bison than in cattle for all rations except the LPHE ration in winter. The responses of serum P paralleled those of BUN.

Blood glucose and cholesterol increased with increased DE. In response to increased CP, blood glucose of both species increased in the summer but decreased in the winter. Season also influenced the effect of DE on cholesterol levels. High energy levels increased cholesterol more in winter than in summer.

In general, ALP increased with increased energy and decreased with increased protein. The relationships between ALP and the levels of CP and DE in the ration were variable, but none of the interactions were significant (Table 4).

In general, there was an inverse relationship between ration CP and blood protein concentration. Total serum protein and TPP generally decreased with increased ration CP. Albumin was not significantly affected by ration CP but several protein interactions were significant for this variable (Table 4). Albumin was largely insensitive to ration CP in cattle. In bison, albumin was positively correlated with ration CP in winter, but negatively correlated in summer. Alpha-globulin decreased with increased protein in winter and increased (in bison) or was not affected by (in cattle) increased protein in summer. Decreased energy reduced α-globulin in winter but had less effect in summer. Total serum protein and TPP increased markedly with decreased energy in cattle but not in bison.

Serum T_4 was significantly affected by species, energy, and the species $\times$ season interaction (Table 4). Thyroxine levels were greater in cattle than in bison and were greater with high energy than with low energy rations. Thyroxine level in bison tended to be higher in winter than in summer while the reverse was true in cattle (Tables 2 and 3).

Sampling Stress

Neither heart rate nor body temperature appeared to be correlated

with subjective estimates of animal stress. In both summer and winter sampling, all animals appeared less stressed during testing of the second pair of rations than during the first. There did not appear to be great differences in sampling stress between bison and cattle. Heart rate in bison fluctuated rapidly with changes of up to 50% occurring within 30 sec. Mean heart rates for bison and Hereford steers were 89 and 93 beats per min respectively, and did not differ significantly between species or among days of sampling ($P>0.05$). Mean body temperatures for bison and cattle were 38.7 and 38.8 C, respectively, and did not differ significantly between species ($P>0.05$). However, body temperature was significantly lower on later sample days in both species ($P<0.05$).

Park Bison

There were no significant differences ($P>0.05$) in the levels of individual blood components between males and females in either bison herd. Most of the adult females sampled at EINP appeared to be in late pregnancy. Few of the adult females sampled at WBNP appeared to be pregnant. Several components varied significantly with age and between park herds (Table 6). The only significant interaction was for ALP; the concentration of ALP was greater in juveniles than in adults in both herds but this difference was greater in bison at WBNP than at EINP. Serum GOT and CPK levels were higher in bison at EINP than at WBNP.

Juveniles that were injured or killed by other bison at WBNP had significantly higher levels of P, ALP, and GOT, and significantly lower levels of MCV, TPP and TSP (Table 6). Creatine phosphokinase was numerically greater ($P>0.05$) in dead juveniles. None of these differences could be attributed to an effect of day of sampling on blood composition.

The concentration of BUN was significantly lower ($P<0.01$) in one juvenile and five adults sampled on the second day of impoundment (17.8 mg/dl) than in 10 juveniles and 13 adults sampled on the first day (25.6 mg/dl). Packed cell volume was significantly higher ($P<0.05$) on the second day (43.9%) than on the first day (39.6%). Neither component varied significantly with age, sex, or whether the animal had been killed prior to sampling (Table 6). No other components varied significantly with day of sampling.

DISCUSSION

Experiments With Formulated Rations

The responses of blood components to nutritional and other factors were complex. Not all responses can be explained with current knowledge and not all will be discussed in detail. The concentrations of blood components in both bison and cattle were within the range of normal bovine values with the exceptions that P and glucose levels of both species were higher than normal values and erythrocytic values in bison were higher than normal bovine values (Kaneko and Cornelius, 1970; 1971). Therefore, differences among species, season, and ration groups must be considered as non-pathological. This is also the case for differences between sex and age classes in the park animals. Our data extend the maximum normal ranges reported for bison for albumin, P, and BUN (Marler, 1975; Mehrer, 1976; Keith et al., 1978). Other measured components fell within reported ranges.

Sampling stress. Increased heart rate and body temperature usually accompany stress and have been found to be useful stress indicators when obtaining blood samples from wild species (Franzmann and Thorne, 1970; Franzmann, 1971; 1972; Franzmann et al., 1975). In the present study, the mean cattle heart rate was within the normal range for animals of similar age (Smetzer et al., 1970). The mean heart rate of the bison was below that of the cattle. Mean body

Table 6. Mean concentration ± one standard deviation of blood components measured in juvenile and adult bison in two national parks and significance of effects in analysis of variance.

	Elk Island National Park		Wood Buffalo National Park			Significance	
Component[a]	Adult (n=c)[b]	Juvenile (d)	Adult (e)	Live juvenile (f)	Dead juvenile (g)	Park	Age
BUN (mg/dl)	11.6 ± 2.8	11.2 ± 2.4	24.4 ± 4.7	23.4 ± 5.3	19.6 ± 3.2	.001	
P (mg/dl)	3.7 ± 1.0	4.5 ± 0.8	3.8 ± 0.9	5.0 ± 1.1	9.9***[l] ± 2.4		.01
ALP (IU/l)	55.5 ± 12.6	75.3 ± 18.8	73.6 ± 27.2	132.9 ± 26.5	229.8*** ± 47.0	.001	.001
CPK (IU/dl)	345.9 ± 328.18	476.2 ± 391.6	80.3 ± 55.2	146.0 ± 118.8	225.8 ± 164.8	.001	
Chol (mg/dl)	77.1 ± 17.4	78.8 ± 11.7	74.8 ± 14.6	69.1 ± 14.1	77.0 ± 25.1		
GOT (IU/l)	232.1 ± 146.6	321.2 ± 149.1	154.1 ± 46.4	189.3 ± 67.0	344.4* ± 196.2	.01	
Glucose (mg/dl)	98.9 ± 15.0	102.0 ± 12.4	115.9 ± 32.6	109.6 ± 29.9	168.2 ± 129.5		
Hgb (g/dl)	16.6 ± 1.4[h]	16.7 ± 0.8	15.8 ± 1.5[i]	14.8 ± 1.5[j]	15.4 ± 2.2	.05	
PCV (%)	45.9 ± 4.1[h]	44.1 ± 2.0	41.3 ± 3.9[i]	39.7 ± 6.4[j]	42.0 ± 6.1	.01	
RBC ($\times 10^6$/mm^3)	7.9 ± 0.6[h]	8.7 ± 0.5	7.6 ± 0.8[i]	7.9 ± 1.2[j]	9.6 ± 2.0		.05
MCV (μ^3)	58.5 ± 4.7[h]	50.8 ± 2.7	53.3 ± 1.9[i]	48.7 ± 2.6[j]	44.0* ± 4.0	m001	.001
MCH (pg)	20.7 ± 2.3[h]	18.7 ± 0.8	21.1 ± 0.7[i]	19.0 ± 1.4[j]	16.8 ± 2.0		.001
MCHC (%)	35.3 ± 3.6[h]	36.7 ± 0.6	38.0 ± 1.8[i]	37.8 ± 2.1[j]	36.7 ± 1.4	.01	
WBC ($\times 10^3$/mm^3)	7.9 ± 1.9[h]	9.1 ± 1.5	8.4 ± 2.2[i]	11.3 ± 1.8[j]	8.7 ± 2.9		.01
Albumin (g/dl)	3.4 ± 0.2[k]	3.3 ± 0.1	3.3 ± 0.4	3.4 ± 0.5	2.9 ± 0.4		
α-glob (g/dl)	1.1 ± 0.1[k]	1.2 ± 0.2	0.9 ± 0.2	0.8 ± 0.2	0.8 ± 0.1	.001	
β-glob (g/dl)	0.7 ± 0.2[k]	0.6 ± 0.0	0.6 ± 0.1	0.6 ± 0.1	0.6 ± 0.2		
γ-glob (g/dl)	2.4 ± 0.4[k]	1.7 ± 0.4	2.7 ± 0.8	1.6 ± 0.4	1.2 ± 0.5		.001
TPP (g/dl)	7.0 ± 0.5[h]	6.4 ± 0.3	7.7 ± 0.7[i]	6.5 ± 0.2[j]	5.5* ± 0.9	.01	.001
TSP (g/dl)	7.6 ± 0.6	6.7 ± 0.4	7.5 ± 0.8	6.4 ± 0.4	5.5* ± 0.9		.001

[a] See Table 2 for abbreviations.

[b] Sample sizes c=14 females; d=3 males + 3 females; e=4 males + 14 females; f=5 males + 6 females; g=1 male + 4 females; h=11 females; i=3 males + 12 females; j=1 male + 5 females; k=13 females.

[l] Within Wood Buffalo National Park, means were significantly different between live and dead juveniles (*P<0.05; ***P<0.001).

temperatures of bison and cattle were similar and within the normal range for cattle (Andersson, 1970). Mean body temperature decreased over successive sampling days, suggesting that the animals were somewhat stressed intially and that this stress decreased with sampling. Overall, however, the data on heart rate and body temperature indicated that neither the bison nor the cattle were severely stressed at the time of blood sampling. Physical trauma was minimal since GOT was within normal bovine ranges and decreased on successive sampling days. Also, the mean GOT of these bison was within 2 IU/l of being equal to the smallest value reported by Marler (1975) in 12 juvenile bison from several herds. The higher GOT in bison suggested greater tissue trauma relative to cattle. However, since CPK did not differ significantly between species and was numerically greater in cattle, the significantly higher level of GOT in bison was probably not related to greater physical trauma.

Within-animal variation. The relatively high within-animal variation may have been related to daily variations in intake, continuing adjustment to the rations, stress-related effects, or other unidentified factors that could affect the experimental animals as a group. Greater within-animal than between-animal variation was also observed in Dorcas gazelles *(Gazella dorcas)* by Bush et al. (1981). Gartner et al. (1969) observed a gradual decline in PCV in cattle during the first week of sampling. This was a stress-induced phenomenon that was not as marked when animals were conditioned to the sampling procedure. The reduction in the concentration of some bison blood components on successive sampling days was not pervasive enough to warrant concluding that there was a trend toward hemodilution. The significant within-animal variation need not cause concern regarding the utility of single samples for reflecting the levels of blood components, since this variation was numerically not great (Table 5). Repeated sampling of the individual would provide a broader estimate of the population variability but did not appear to be essential to evaluate the effects of ration composition and season on blood composition in our study.

Species comparisons. Bison had a significantly greater PCV, more numerous erythrocytes, and a greater concentration of Hgb than did Hereford cattle when age, season, and ration were similar between species. Mehrer (1976) and Marler (1975) also observed that erythrocytic values of bison were greater than published normal values for cattle. The oxygen carrying capacity for adult bison reported by Haines *et al.* (1977) exceeded values reported for several domestic ungulates, including cattle. Greater erythrocytic values in wild versus domestic, phylogenetically similar species, have also been observed between domestic sheep *(Ovis aries)* and bighorn sheep *(Ovis canadensis)* (Franzmann and Thorne, 1970; McDonald et al. 1981). There can be differences between breeds in PCV, however. Young et al. (1977) observed hematocrits in pairs of Hereford, Holstein, and Highland cows of 37.1%, 42.1%, and 45.3%, respectively. The mean hematocrit of two bison in the same study was 45.5%.

Packed cell volume, RBC, and Hgb can increase with excitement (Searcy, 1969; Swenson, 1970). Wild animals are likely to be more excited than domestic animals during blood sampling and this could contribute to the greater erythrocytic values observed in wild species. However, tamed bison did not appear to be more stressed than cattle during sampling in the present experiments.

Blood urea nitrogen was greater in bison than in cattle with a variety of CP and soluble carbohydrate levels in the ration. Because the recycling of urea to the rumen may be proportional to the level of urea in the blood over a wide range of concentrations (Houpt, 1970;

Engelhardt, 1978), our results somewhat support the theory that bison recycle more urea to the rumen than do cattle (Peden et al., 1974; Hawley et al., 1981b). The greater depression of BUN in bison when ration DE increased is in accord with this theory. If more BUN were recycled to the bison rumen, then more nitrogen could be incorporated into rumen bacterial protein in response to elevated soluble energy in the ration. The lower BUN in bison than in cattle with the LPLE ration in winter may be related to a lower rate of intake by bison with poor quality rations in winter (Hawley et al., 1981a).

Higher levels of cholesterol in cattle were most evident with high energy rations, especially in winter (Table 3). Blood cholesterol concentration is dependent on total energy intake (White et al., 1968). Under feedlot conditions, bison may consume less than cattle, especially in the winter, and there are species differences in utilization of high quality rations (Reynolds et al., 1982). The species difference in blood cholesterol may have been related to differences in total energy intake. The inverse relationship between cholesterol and ration CP may reflect differences in the use of energy for muscle and bone growth, as opposed to fat and steroid synthesis. Low protein intake can limit muscle and bone growth, while digestible energy is stored as fat (McMeekan, 1940). At high protein intakes, more digestible energy can be used for growth of non-adipose tissue.

Ration comparisons. Of all blood components, BUN was most significantly affected by ration CP, reflecting the high correlation between BUN and the level of CP in the ration (Preston et al., 1965; Bahnak et al., 1979). The depressive effect of increased DE on BUN is in agreement with previous observations (Preston et al., 1961; 1965; Kirkpatrick et al., 1975). There are several possible explanations for this depressive effect. First, energy supplementation primarily involved an increase in the proportion of soluble carbohydrates. Energy availability in the rumen increases under these conditions. Ammonia utilization is thereby improved and less ammonia is lost from the rumen into the animal's circulation. This type of interaction was exemplified by the observations of Parker and Blowey (1976) who found no consistent relationship between digestible CP and BUN in 15 dairy herds but a high inverse correlation between BUN and the ratio of starch equivalent to digestible CP in the same herds. Blood urea nitrogen was also inversely related to energy intake in white-tailed deer fawns *(Odocoileus virginianus)* (Kirkpatrick et al., 1975). Second, insufficient energy intake might also elevate BUN through increased tissue catobolism and deamination of amino acids to meet energy requirements. This effect was evident in pregnant domestic ewes and white-tailed deer on restricted intake (Guada et al., 1976; Bahnak et al., 1979). Extensive tissue catabolism is reflected by an increase in the levels of tissue enzymes in the blood (Kaneko and Cornelius, 1971). Since there was no elevation in CPK or GOT in animals receiving experimental rations in the present study, the inverse relationship between DE and BUN is attributable to an intraruminal effect of available energy on nitrogen utilization. The positive correlation between serum P level and ration CP agrees with the observation of Keith et al. (1978). This correlation may be related to a high proportion of phosphoproteins in the protein sources in the rations.

Blood glucose concentration has been correlated with energy intake and has been related to propionate production in the rumen (Ullrey et al., 1968; Bowden, 1974; Guada et al., 1976). In our experiments, the greater amounts of grain in the high energy rations would have increased propionate production and thus facilitated gluconeogenesis, thereby accounting for the increase in blood glucose with increased DE in the ration.

The responses of blood cholesterol to increased DE in this study are in agreement with the general observation that blood cholesterol reflects total energy intake (White et al., 1968). Seasonal differences in the response of blood glucose and cholesterol to ration CP and DE levels may have been related to seasonal differences in metabolism and nutrient partitioning.

The level of serum ALP appears to be an index of growth. Serum ALP increases with increased osteoblast activity and is proportional to the rate of bone formation (White et al., 1968; Searcy, 1969). Serum ALP has been observed to be higher in juveniles than in adults in pronghorns *(Antilocapra americana)*, bison, elk *(Cervus elaphus)*, and Dorcas gazelles (Marler, 1975; Pedersen and Pedersen, 1975; Barrett and Chalmers, 1977; Bush et al., 1981). The positive relationship between ALP and ration DE in our study could be related to the positive association between ALP and growth. Serum ALP was inversely related to ration CP. This was primarily due to an inverse correlation in the winter, perhaps as a result of seasonal differences in nutrient partitioning.

The relationship between PCV and feed composition appears complex. The significant seasonal effects and interactions could be related to ration-independent seasonal variation in PCV such as has been observed in other ruminants (Bahnak et al., 1979). In our experiments, packed cell volume and RBC decreased with increased DE in the ration in the summer. Kitts et al., (1956) postulated that starvation to the point of death could occur in black-tailed deer *(Odocoileus hemionus)* without altering PCV. However, several studies have indicated positive correlations between PCV and animal condition (Rosen and Bischoff, 1952; Franzmann, 1972; Franzmann and LeResche, 1978). In wild populations, changes in animal condition cannot usually be dissociated from general seasonal influences. In our experiments, no correlations were attempted between PCV and indices of animal condition. Variations in PCV were observed with changes in ration composition and over relatively short periods of time.

The large negative effect of DE on serum proteins might account for the small but significant negative relationship observed between ration CP and serum proteins. Blowey et al., (1973) and Hyvärinen et al., (1975) observed positive correlations between serum proteins and ration CP. In the present study, the negative relationship was most evident in winter. Most components of serum protein had significant seasonal interactions (Table 4). Glucose, ALP, PCV, RBC, and Hgb also displayed significant seasonal interactions and all were negatively correlated with ration CP in winter, but were positively correlated with, or were not affected by, ration CP in the summer. Some unidentified seasonal metabolic changes may have been operative. Seasonal variation in ration CP levels (Table 1) may have also had an interactive effect on blood protein levels.

Cattle had a higher level of circulating T_4 than bison (Tables 2 and 3). Young et al. (1977) also observed a higher level of T_4 in cattle, although triiodothyronine was greater in bison. Circulating T_4 correlates with metabolic rate, and cattle have been observed to have a higher metabolic rate than bison during the winter (Christopherson et al., 1979). Cattle also have a higher growth rate when both species are fed nutritionally adequate rations (Reynolds et al., 1982). Circulating T_4 increased with increased DE in our study. Increased T_4 also correlated with the higher levels of ALP observed with high energy rations. Thyroxine was not significantly affected by season, although the animal species × season interaction was significant. Thyroxine increased in bison and decreased in cattle in the winter. This contrasts with a reduced growth rate and

metabolism observed in bison in winter (Christopherson et al., 1979; Hawley et al., 1981a). Unidentified factors such as variations in intake, ration sorting, and metabolism may have influenced results with this and other blood components.

Park Bison

The absence of a significant effect of sex on blood composition in bison agrees with the observation of Marler (1975) and Mehrer (1976). There were several significant differences in blood composition between herds. Since few of the adult bison at WBNP were pregnant females, differences between herds may have been compounded by an effect of pregnancy on blood composition. We were unable to determine what contribution pregnancy might have made to differences between herds. Pregnancy was the only variable not influencing blood components measured in moose by Franzmann and LeResche, (1978). Beta-globulin and α-globulin were observed to increase in late gestation in cows (Schalm et al., 1975) and RBC and Hgb showed a tendency to decrease in late gestation in sheep (Reda and Hathout, 1951). These differences were not reflected in the differences we observed between EINP and WBNP bison. Pregnant white-tailed deer displayed a greater reduction in BUN during late pregnancy when receiving a low-protein ration than when receiving a high-protein ration (Bahnak et al., 1979). A similar effect in bison may have contributed to the relatively low BUN in EINP adults.

The level of BUN in bison at WBNP was higher than that in bison at EINP and was as high as the highest mean observed in bison receiving formulated rations. This high level of BUN in WBNP bison can be attributed to the fact that these animals were sampled at a time when the CP content of native vegetation was near its annual peak.

The decrease in BUN in bison impounded for 24 hr at WBNP might be attributable to decreased feed intake accompanying capture stress. Hyvärinen et al., (1975), Franzmann and Thorne, (1970) and Barrett and Chalmers, (1977) observed increases in BUN in reindeer *(Rangifer tarandus),* bighorn sheep, and pronghorns, respectively, after 1 or 2 days of impoundment. In the latter two instances, the increase in BUN could be attributed to tissue degradation and increased protein catabolism as evidenced by an increase in GOT. In the bison at WBNP, mean GOT was numerically lower on the second day of impoundment, indicating that tissue damage was not extensive or that tissue enzymes had not yet entered the blood stream in quantity. The higher levels of CPK and GOT in animals at EINP than at WBNP may have been attributable in part to a longer confinement period before sampling at EINP. Genetic differences may have made unknown contributions to these and other differences between herds.

The increase in PCV in impounded bison was similar to an increase in PCV observed in bighorn sheep 48 hr after capture (Franzmann and Thorne, 1970). Excitement and physical activity can increase PCV and would account for the increase in PCV with impoundment (Searcy, 1969; Swenson, 1970). Also, increased respiratory water loss during roundup and possibly reduced water intake during impoundment might accentuate an increase in PCV.

The greater level of ALP in juveniles than in adults in both herds agrees with earlier findings (Searcy, 1969; Barrett and Chalmers, 1977; Bush et al., 1981). The difference between age classes in ALP level was greater in bison at WBNP than at EINP. This may have been related to differences in date of sampling. The bison at WBNP were sampled when the animals were farther into their annual growth cycle than at EINP. Keith et al., (1978) observed a peak in ALP in June, which was also the sampling time of WBNP animals. The ALP levels reported by these authors for adult bison

were lower than values in adult bison at WBNP and EINP. Phosphorus levels were also higher in juveniles in our study and in that of Bush et al., (1981). Higher P levels in the young could be related to the higher levels of ALP and osteoblast activity. In contrast to Mehrer (1976), we observed that RBC was higher and MCV lower in juvenile animals.

The serum levels of CPK and GOT were higher in park bison than in tamed bison receiving experimental rations. This was attributable to the rougher handling of the less tractable park bison resulting in some tissue damage. The stress on bison and death of some juveniles during the WBNP roundup have been described (Hudson and Tennessen, 1978). The elevated levels of tissue enzymes in the serum of the dead animals was caused by the massive tissue trauma accompanying trampling and goring. The absence of significance in the large increase in mean CPK in dead animals can be attributed to the large variation accompanying this value (Table 6). The higher WBC levels in park bison than in bison receiving experimental rations may suggest greater disease exposure in the park animals. The levels displayed by the park bison were comparable to those displayed by cattle in this study (Tables 2 and 3).

Bison and cattle displayed similar levels and responses to experimental manipulation for many blood components. For other components such as BUN and hematologic values, there were distinct species differences. Impoundment of wild bison and trauma during handling altered some bison blood components and these effects should be considered when interpreting results from bison blood analyses. Further research involving control of intake, feed composition and digestibility, feeding schedules, and environmental conditions is required to determine the precise nature of nutritional and seasonal effects on blood composition in both bison and cattle. The many significant changes in blood composition associated with changes in ration composition support the use of blood composition as an index of nutritional status (Blowey et al., 1973; Bowden, 1974; Torell et al., 1974; Parker and Blowey, 1976; Franzmann and LeResche, 1978).

Acknowledgements

Thanks are extended to R. Jones, former Chief Warden, Elk Island National Park, for his assistance in obtaining bison and in taking blood samples at the park. We thank B. Lieff, Superintendent, Wood Buffalo National Park, for support and assistance in obtaining blood samples from bison at Wood Buffalo National Park.

All blood analyses were conducted by the Clinical Pathology Laboratory, Western College of Veterinary Medicine, University of Saskatchewan, Saskatoon. The assistance of D. Olexson, Western College of Veterinary Medicine, in this regard is gratefully acknowledged.

We thank E. Driver, Canadian Wildlife Service, Saskatoon, and M. Barrett, Alberta Environmental Centre, Vegreville, Alberta for their valuable reviews of this manuscript.

The senior author received support from the Alberta Environmental Centre, Vegreville.

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Received for publication 27 July 1981